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Original article

Locked plating for internal fixation of the adult distal femur: Influence of the type of construct and hardware on the clinical and radiological outcomes

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ABSTRACT

Introduction: Distal femoral fractures are rare and serious. Along with traditional internal fixation, new, dedicated hardware have appeared (distal nails, locked plating). We report the results of a multicenter prospective study of these fractures treated with locked plating.
Hypothesis: The short-term results are satisfactory and related to the type of construct and the hardware used, with better results for elastic assemblies and titanium implants.
Materials and methods: From June 2011 to May 2012, 92 patients, mean age 64 years, were included in 12 centres. The fractures were classified as follows: 44 type A, 7 type B, and 41 type C according to the AO classification. Thirteen fractures were open. The plates were uniaxial. The assemblies were elastic in 52 cases, rigid in 26, and unconventional in 14.
Results: Seventy-six patients underwent a radiological follow-up at 6 months and 66 patients had a clinical result evaluated at 1 year. The mean range of motion was 100° and the mean IKS score was 122. The bone union rate was 87% within 12 weeks. Seven valgus, two varus, ten flexion deformities, and three recurvatum greater than 5° were observed (19.5%). Revisions involved two cases with loss of fixation, five cases of infection, and one case of arthrofibrosis (requiring arthroscopic arthrolysis). Secondary bone grafting was carried out in seven cases (four successfully). No influence of the type of assembly or the hardware used was demonstrated.
Discussion: The results remain modest, underscoring the severity of these fractures. Neither the type of construct nor the hardware used influenced the radiological and clinical outcomes. The hypothesis was not confirmed.
Level of evidence: Level IV prospective, non-comparative study.

1. Introduction

Distal femoral fractures are rare [1] and serious, with high morbidity and mortality [2,3]. Only surgical treatment can work against the static bone forces and dynamic muscle forces [4]. Different options are available: anterograde nailing [5], retrograde nailing [6–8], blade-plate fixation [9], screw and plate fixation [10], isolated screw fixation [11,12], locked plating [7,8,10,13–16], or external fixation for particular indications of damage control [17,18]. The choice of the material depends on the type of fracture, its environment, the surgical method, and the surgeon's experience. There is no consensus [4]. Many publications report satisfactory results with locked plating [7,8,10,13–16]. The debate also revolves around the material to use: titanium or steel. The literature is not unequivocal,

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even if it has been shown that titanium plates allow earlier weight-bearing and facilitate bone union [14,19,20].

The objective of this study was to report the results of a multicenter prospective study of distal femoral fractures treated with locked plating. This type of internal fixation responds to strict rules, with specific assemblies (elastic or rigid) corresponding to precise definitions. The working hypothesis was that the results would be satisfactory and influenced by the type of assembly and material, with an advantage using elastic assemblies and titanium implants.

2. Patients and methods

2.1. Study design

This was a multicenter, prospective, and continuous study conducted in 12 centres in France over a 1-year period (June 2011 to May 2012), with a minimum follow-up of 1 year, under the aegis of the Société Française de Chirurgie Orthopédique et de Traumatologie (SoFCOT) and presented within a symposium at the 88th SoFCOT conference (November 2013). Distal femoral fractures (supracondylar, condylar, supra- and intercondylar) within the distal segment square according to the AO criteria [21], with first-line treatment using locked plating, independently of the existence of a proximal homolateral implant (hip prosthesis, osteosynthesis were included). The type of material, the manufacturer, the surgical technique, and the indications were left to the discretion of the local teams. Pathological fractures, context of a knee prosthesis or open growth cartilage, were excluded.

2.2. The series

The series included 92 cases (54 females, 38 males), mean age, 64.2 years (range, 20–101 years; median, 67 years) (Table 1). Articular fractures were more frequent ($n = 48/92$, 52%).

No tendon or nerve lesions were demonstrated initially, but compression of the femoral artery was observed once, which resolved spontaneously.

Surgery was performed by a senior surgeon in 63 of 92 (68.5%) cases and by a junior surgeon in 29 of 92 cases. Table 2 details the surgical data.

Table 1
Epidemiologic data.

Parameters	Results
Place of life	Home: 74/92 (80.5%) Retirement home: 12/92 (13%) Long stay: 6/92 (6.5%)
Parker and Palmer score [22]	4.9 (0–9, med 4)
Bony mass index	25.5 (14.8–41.6, med 24.9)
ASA [23]	2 (0–4, med 2)
Initial Trauma	63 (68,4%) domestic injury 23 (25%) traffic accident 4 (4.4%) high energy fall 2 (2.2%) paragliding
Associated Injuries	66 (71.7%) isolated 5 floating knee 9 bilateral cases 13 (14.1%) polyfracture 5 (5.5%) polytraumatism 8 (8.7%) polyfracture + polytraumatism
Proximal femoral implant	19 Hip arthroplasty 8 osteosynthesis
Open fracture (Gustilo) [24]	3 types I 8 types II 2 types IIIA
Fracture type (AO classification) [21]	44 (47.8%) types A 7 (7.6%) types B 41 (44.6%) types C

Each surgeon was asked to define the assembly used according to his or her knowledge of the locking system: in 55 cases, it was labelled rigid and in 37 elastic. With reference to the literature, a second reading was done (ME) [4,13,14]. An assembly was considered rigid when it was short, the locking screws were close to the fracture and placed side-by-side. An assembly was considered elastic when it was long (at least five holes beyond the fracture in the proximal direction), the locking screws were separated by free holes, the locking screw was separated from the fracture by a free hole if the fracture was stable (short oblique, transversal, short spiroid) or near the fracture when it was complex. Certain assemblies, described by the surgeons as a locking assembly, had no locking screws above the fracture. They were identified using the term "unconventional" with an assembly approaching a locking blade-plate fixation. The analysis of postoperative x-rays demonstrated 26 rigid assemblies (Fig. 1), 52 elastic assemblies (Fig. 2), and 14 unconventional assemblies (Fig. 3). Thus, compared to the descriptions given by the surgeons, 24 assemblies labelled rigid (24/55, 44%) and 32 labelled elastic (32/37, 86%) matched the actual assemblies.

Rehabilitation was left free in 42 cases (45.7%) and was limited in 50 cases (54.3%). It was begun immediately in 71 cases (77.2%) and deferred for 21 patients (22.8%). For the 68 documented cases, partial weight-bearing was authorized at a mean 59.5 days (range, 0–270 days; median, 45 days). For the 65 documented cases, complete weight-bearing was authorized at a mean 78 days (range, 0–270 days, median 60 days).

2.3. Assessment method

The follow-up was prospective with a minimum follow-up of 1 year for the clinical results and 6 months for the radiological results. The clinical assessment noted joint mobility, autonomy according to the Parker and Palmer score [22] for patients over 65 years of age, functional recovery according to the IKS score [25], and complications. The radiographs were analyzed immediately after surgery until bone healing, which was deemed acquired when two cortices were solid. Non-union was defined as the absence of bone union at 6 months. Malunion was considered beyond 5° of fracture angulation in any plane.

Table 2
Surgical data.

Parameters	Results
Operating time (min)	110 (60–150, med 120)
Anesthesia	General anesthesia: 84/92 (91%) Rachianesthesia: 8/92 (9%)
Tourniquet	22/92 (23,9%)
Set-up	Standard table: 71/92 (77.2%) Traction table: 21/92 (22.8)
Surgical technique	Open surgery: 73/92, (9.4%) Mini-invasive surgery: 19/92 (20.6%)
Mono-axial plate	100%
Material	Titanium: 45/92 (48,9%) Steel: 47/92 (51.1%)
Type of plate	Depuy-Synthes®: 67/92 (72.8%) Zimmer®: 16/92 (17.4%) Stryker®: 9/92 (9.8%)
Combined surgery	Intercondyar screw: $n = 11$ (11,9%) 10 for type C 1 for type B Wiring: $n = 10$ (10,8%) 6 for type A 4 for type C
Osseous graft	2 autografts 2 substitutes 1 autograft + substitute

Fig. 1. Rigid assemblies. A. Short assembly, side-by-side locking screws above the fracture. The monocortical diaphyseal screw with a free hole does not compensate the substantial rigidity of the three bicortical locking screws. B. Side-by-side locking screws, rigidifying the assembly.

2.4. Statistical analysis

The groups were compared on the qualitative variables using the Fisher exact test and on the quantitative variables using the Mann–Whitney test when two groups of independent variables were compared and the Wilcoxon test when two groups of paired variables were compared. When comparing more than two groups of independent quantitative variables, the Kruskal–Wallis test was used. The significance threshold retained was $P < 0.05$.

3. Results

3.1. The series

At 6 months, four patients had died and 12 were lost to follow-up (17.4%). Bone union assessment was therefore possible for 76 patients. At 1 year, the clinical evaluation was based on 66 patients (71.7%) (nine dead [9.8%] and 17 lost to follow-up [18.5%]).

3.2. Clinical results

At 1 year, the mean range of mobility was 100°. The total IKS score was evaluated for 50 patients (75.8% of the patients seen at 1 year) and the mean was 122. The decrease in the Parker and Palmer score was significant ($P < 0.05$) between the pre- and post-operative times (Table 3).

No influence of the type of material (titanium or steel) or of the type of assembly (elastic, rigid, unconventional) was demonstrated (Tables 3 and 4).

A majority of the patients remained in their preoperative residence (56/66, 84.8%): 48 at home, five in a retirement home, and three in a long-term care facility. Five (7.6%) were still in a rehabilitation centre and five (7.6%) required a facility offering closer medical attention, underscoring these patients' dependence.

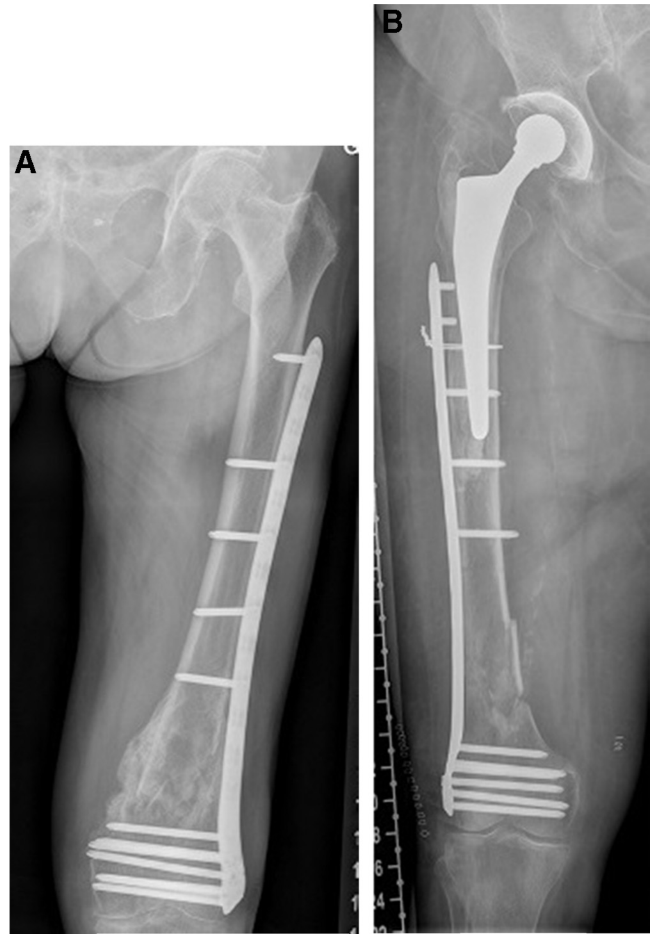

Fig. 2. Elastic assemblies. A. Locking screws spaced alternately with a free hole, long assembly, and fixation near the fracture site because this was a complex fracture. B. Long assembly, alternating locking screw and free hole. Note the bridging of the prosthesis in place so as to avoid a fragility zone between the two implants.

Table 3
Clinical results at 1-year follow-up.

	n	Results
Range of motion		
ROM	66/92	100° (50–140, med 105)
Flexion	66/92	105° (50–140, med 110)
Extension lag	24/92	8° (5–20, med 10)
IKS [25]		
IKS total	50/92	122 (29–199, med 120)
IKS knee	50/92	71.6 (29–99, med 76.5)
IKS function	50/92	50.2 (0–100, med 52.5)
Parker and Palmer score [21]	41	3.56 (0–9, med 3)

n: number of case; ROM: range of motion.

3.3. Radiological results

No influence was demonstrated for the type of material (titanium or steel) or the type of assembly (elastic, rigid, unconventional) (Table 4).

At 6 months, bone union was obtained for 66 out of 76 patients (87%) within a mean 12 weeks (range, 6–24 weeks; median, 12 weeks) (including two early autografts performed on principle). Of the ten non-union cases, three did not undergo a second surgery and had not achieved bone union at 1 year. Seven bone grafts (auto- or allografts), associated in four cases with fixation material changes and in one case with bone morphing protein, were performed within a mean 30.8 weeks (range, 6–70 weeks). Bone

Table 4
Clinical and radiological Results according surgical to technique.

Parameters	*n*	Healing (number of patients)	*P* value	Time of healing (weeks) (extremes)	*P* value	Malunion (number of patient)	*P* value	IKS total score [25] (extremes) (number of patient)	*P* value
Expertise of surgeon			NS				NS		NS
Junior	29	82.6% (19/23)		12.8 (8–24)	NS	17.3% (5/29)		107.1 (29–191) (16/29)	
Senior	63	88.7% (47/53)		11.9 (6–24)		20.6% (13/63)		128.7 (43–199) (34/63)	
Set-up			*P* < 0.04				NS		NS
Traction table	21	73.7% (14/19)		12.6 (8–24)	NS	19% (4/21)		100.5 (44–186) (12/21)	
Standard table	71	91% (52/57)		11.9 (6–24)		19.7% (14/71)		128.5 (29–199) (38/71)	
Surgical technique			*P* < 0.006				NS		NS
Mini-invasive	19	73.4% (11/15)		11.2 (8–16)	NS	10.5% (2/19)		91.2 (44–164) (9/19)	
Open	73	90.2% (55/61)		12.6 (6–24)		21.9% (16/73)		128.5 (29–199) (41/73)	
Material			NS				–		NS
Steel	47	89.2% (33/37)		11.6 (6–24)	NS	–		115.7 (42–186) (27/45)	
Titanium	45	84.6% (33/39)		12.4 (6–24)		–		130.2 (29–199) (23/47)	
Type of assembly			NS				NS		NS
Elastic	52	92.5% (37/40)		12.3 (6–24)	NS	15.4% (8/52)		113.5 (42–199) (26/52)	
Stiff	26	77.3% (17/22)		11.4 (8–24)		23% (6/26)		122.2 (29–199) (13/26)	
Non compliant	14	85.7% (12/14)		12.4 (8–24)		28.6% (4/14)		141 (80–186) (11/14)	

n: number of case; NS: no significant.

Fig. 3. Unconventional assembly. Presence of locking screws in the epiphyseal-metaphyseal portion and presence of standard proximal diaphyseal screws. This assembly comes close to a "blade locking plate" assembly. A locking assembly by definition should include locking screws on either side of the fracture.

union was obtained in four cases at 17 weeks (range, 12–25 weeks) after the graft (41 weeks after the fracture [range, 30–50 weeks]). Malunion greater than 5° was found in 22 cases; in 14 cases it was isolated: seven valgus (mean, 10°; range, 6–10), two varus (7 and 12°), ten recurvatum (mean, 12°; range, 6–20°), and three flessum (10, 10, and 15°). In four cases, it was combined. The follow-up was insufficient to assess arthritic progression.

3.4. Complications

Twelve complications were observed: three medical complications (one case of phlebitis, one of distal ischemia of the lower limb independent of the fracture, and one of decompensated cirrhosis) and one cutaneous complication that progressed favorably with local treatment. Five infections were noted within a mean 15 days (range, 5–28 days), resulting in, after revision, clearing the infection but requiring arthrodesis in two cases. Two cases of disassembly were observed: one at the 25th week requiring surgical revision and fixation replacement (a new plate), which progressed favorably. The second at the 6th postoperative day with a rigid assembly, without initial revision, complicated on the 14th day with a proximal fracture stabilized with an anterior plate associated with cerclages. Arthroscopic arthrolysis was performed at the 6th month for flexion limited to 90°, with favorable progression (range, 0–130°).

4. Discussion

The results reported herein remain modest but are comparable to the results published for the different therapeutic options available [4,26]. However, all the problems have not been solved and the extreme rigidity of the material is questioned given the problems achieving bone union and implant breakage [26–29].

This study presents limitations despite its prospective design. Several centres participated in this study, each with its own practices. This disparity, reflected by the variability of the assemblies performed, is a bias. Finally, at 1 year, 18.5% patients were lost to follow-up and 9.8% had died. These high percentages should be compared to the epidemiology and notably the aging of this population.

The variability of the assemblies observed in this study underscores the lack of theoretical knowledge prompted by the biomechanical complexity of locking systems. An educational flaw seems to be the main explanation. Despite a decade of existence, the implantation rules and the definitions of the different assemblies are still not common knowledge. Nonetheless, the statistical analysis of the results of this study did not demonstrate an influence of the material or the type of assembly on the results, contradicting our hypothesis. As for the bone union rate, no statistically significant difference was shown, even if a better rate was found for elastic assemblies than for rigid assemblies (92.5% versus 77.3%). Contrary to what has been reported in the literature, it was not possible to demonstrate the advantage of titanium on bone union [19,20]. For Lujan et al. [20], the volume of osseous callous formation was significantly greater at the 6th, 12th, and 24th weeks with the titanium plates.

The modest clinical results obtained underline the severity of these fractures, but they are comparable to the data reported in the literature for all surgical treatments [4,26]. The radiological results should be taken with precaution (87% bone union, 19.5% malunion, 2.2% disassembly). The bone union rate corresponds to the lower limit of the data in the literature, whereas the malunion rate is higher, but the pathological threshold for the present study is more severe (> 5°). Smith et al. [29] reported 19% loss of reduction, 6% bone union delay or non-union, and 5% mechanical failure. They specify that the majority of complications were observed before 2005, demonstrating an inherent learning curve for this new material and this new philosophy. The failures observed were most often late (75% after 3 months, 50% after 6 months) [27], which must be compared to bone union problems. Nonetheless, the time to bone union is comparable, oscillating between 11 and 30 weeks [27,29], but this difference can be explained in part by a definition of bone union that varies depending on each author.

Zlowodzki et al. [26] reported comparable non-union rates between locking plates, nailing, and the other plates, even if the relative risk is lower for locking plates. However, more disassemblies were observed for locking plate systems (4.9%) than for nailing (3.2–3.7%) and other plate fixations (2.6%). The authors conclude that surgical experience is a favorable factor in the risk of non-union and surgical revision, with the threshold set at 21 fractures per surgeon. At the end of a prospective study, comparing locked plating and retrograde nailing, no difference was shown in terms of the radiological results [8]. Kao et al. [10] compared locked plating systems and compression screw and plate fixation, with the only difference being a lower rate of mechanical failure for the compression screw and plate fixation group. Finally, Vallier and Immler [9] compared locked plating with blade plating. They observed more non-union, malunion, and infection for locked plating, as well as a statistically significantly higher surgical revision rate. The risk factors they identified were female gender, age, and low-energy fracture.

5. Conclusion

The results reported herein are comparable with those reported in the literature, no matter which material or assembly is used, underscoring the severity of these fractures. The present study does not confirm the initial hypothesis. In fractures of the distal femur, locked plating systems do not solve all problems. The hopes for the assumed superiority of locked plating are not confirmed. Despite more than a decade of existence, the philosophy of these locked assemblies has not extended to all surgeons, making it necessary to update knowledge. Many publications on the mechanics of this material prove that it is complex but that it is evolving. Better expertise in this area is expected but remains ambiguous.

Disclosure of interest

ME: educational consultant for Depuy-Synthes®.
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FD, LP, GP, EVD: none.

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